Method for monitoring at least two people carrying an external respiratory air supply

This invention relates to a method for monitoring at least two people carrying out a time-limited activity using an external respiratory air supply, especially people carrying breathing equipment such as firemen, divers or the like, according to which method filling levels of the breathing equipment, especially compressed-air bottles, supplying people with respiratory air, are determined and transmitted to a control center for monitoring before said people make their way to the operation area, and once the people have arrived at the operation area, they transmit a signal indicating their arrival to the control center, said signal being used to calculate the period of time between the time of arrival and the beginning of the inhalation of respiratory air from the breathing equipment. The invention further relates to an apparatus for carrying out the method for monitoring at least two people carrying out a time-limited activity using an external respiratory air supply, especially people carrying breathing equipment such as firemen, divers or the like.

Activities of persons which require the use of an external respiratory air supply, for example activities of firemen or divers, must be precisely monitored for the operation time, since the respiratory air to be carried along in so-called breathing devices is limited. The required amount of respiratory air varies from person to person and therefore requires continuous monitoring. In this context, the degree of the physical exertion during the operation as well as the individual oxygen requirement dependent of a person's height and weight are particularly important. For example, when firemen are in action, the beginning of their work with use of a breathing device, the respiratory air supply in said breathing device as well as the time needed for reaching the operation area must be determined in order to determine from these values the point of time for leaving the operation area, to secure for the person carrying the breathing device a sufficient supply of respiratory air that is needed during the time from leaving the

operation area until the arrival at an atmosphere where sufficient respiratory air is available.

Such breathing equipment is used both by firemen and in the industry, when persons move in atmospheres which do not allow natural breathing due to lacking oxygen content in the ambient air. In fire brigades working teams are normally made of a number of persons, each team usually having one team leader. The whole brigade is monitored by a monitoring person who as a rule communicates with the team leader via a radiotelephone system. At large-scale operations it is sometimes required out of personnel reasons that one monitoring person monitors several working teams, by which fact the source of error is drastically increased. For example, the state of the art is that the monitoring person is in contact with the individual team leaders of the operating teams via radiotelephone and inquires the data relevant for monitoring. The monitoring person then enters these data in prepared tables and calculates on the basis of these data the pressures in the breathing equipment which are required for the withdrawal from the operation area and which are equivalent to the respiratory air supply, and calculates the times resulting there from, so that the team leaders are informed via radiotelephone by which time their respective teams have to begin withdrawing from the operation area.

In prior art, this method has been correctly considered as disadvantageous, because the responsibility of the monitoring person is very high, particularly in dangerous operations, so that the error rate may increase due to stress situations.

From the document WO 02/086834 A1 there is known a monitoring and warning system for firemen and people similarly at risk, which system comprises a plurality of monitoring, warning and control devices as well as a telemetric module for transmitting information to the base station and for receiving commands. All the units of the system are connected to a common – open or closed – bus in a

galvanic or galvanically separate fashion, namely either for the master/master or the master/slave operation. Though this pre-known device works quickly and safely without requiring complicated connection systems and may be easily retrofitted, it has the disadvantage that the units, especially the telemetric data transmission units of this system, are complicated and expensive. In addition, this system is not compatible with the equipment like breathing equipment and radiotelephony devices already existing with corresponding facilities like fire brigades.

Furthermore, from the document EP 1 077 742 A1 a system is known for monitoring persons carrying breathing equipment. This system includes a mobile part and a base station. To reduce the risk for persons carrying breathing equipment the system data are constantly transmitted to the base station through a mobile part mounted to a compressed air breathing device. To this end the mobile part is equipped with a radio transmitter. In response to the system data alarm and warning signals are transmitted visually and/or acoustically both to the person carrying the breathing device and a monitoring person. Accordingly, from this document a monitoring system is known which essentially works automatically and which informs at all times during the operation the condition of (all) the breathing device(es) to its(their) carrier(s) among a team and to the monitoring person responsible for this team and in the emergency case releases an alarm both on the side of the person carrying the breathing device who is in an emergency and on the side of the monitoring person. However, the technology that is used here is very complicated and expensive and requires a considerable number of devices, particularly in large-scale operations where a great number of breathing devices has to be monitored. In addition, the great number of devices requires the provision of a plurality of radio channels, since each single breathing device must be monitored constantly, with a constant transmission of the data of the individual mobile parts independently from each other.

A further device for monitoring persons carrying out a time-limited activity, in particular firemen equipped with breathing devices, is known from the document DE 197 42 758 C2. This monitoring device has a timer for setting a time period necessary for safety reasons for an operation carried out by a person to be monitored, a time measuring device for measuring the time that has elapsed since the start of the time measuring device, an activation device with which the person to be monitored is equipped for activating the time measuring device, a warning device for releasing a first visual and/or acoustical warning signal for indicating that a first fraction of the time period set has elapsed after the actuation of the activation device, a confirmation device for deactivating the warning device of an alarm device for releasing a visual and/or acoustical alarm signal for indicating that the time period set has elapsed after the actuation device has been operated, and a further confirming device with which the person to be monitored is equipped and which can be actuated by said person in order to deactivate the alarm device. This device enables one or several persons belonging to one group to be monitored for whether the maximum admissible time period that has been fixed for reasons of safety for the activity to be carried out by said person or persons is exceeded. Each person to be monitored checks out at the monitoring device at the beginning of her activity. This is effected by the operation of the actuation device, by means of which the time measuring device for measuring the time that has elapsed since the check-out is started. If several people of a group are to be monitored, the time measuring device is started with the check-out of one person belonging to this group. After the expiration of a first fraction of the time period set, for example after the expiration of 50% of this time period, a visual and/or acoustical warning device is activated which releases a visual and/or acoustical warning signal for signalising the expiration of this first fraction of the time period set. A person who is within the area of the monitoring device and who is, in addition to other tasks, responsible for the control of the monitoring device can now deactivate the warning device by operating the confirmation device. In addition, this person may contact the persons in the operation area to be monitored via radio in order to inform them

about the expiration of a part of the time period set. Preferably, said warning device together with the acoustical and/or visual signal also outputs a signal which is received by the persons in the operation area or by any other existing control center, in order to draw attention in this way to the expiration of a part of the preset time period. But this pre-known device is only suitable for indicating particular time intervals, without taking into account the real situation during an operation in a dangerous area as herein discussed.

Finally, from the document DE 199 05 304 A1 a monitoring system for persons carrying breathing equipment is known which comprises at least one central unit and at least one portable unit carried along by a person carrying breathing equipment, which unit is adapted for acquiring data relating to the operation carried out by the person in the operation area carrying the breathing device and for communicating with the said person carrying the breathing device, as well as with other persons carrying breathing devices and/or with the central unit, in dependence of the operation data. This system, too is a telemetric data system which is complicated and accordingly expensive. This system detects temperatures, movements, pressures etc. which are transmitted to the control center, i.e. to a receiving unit, from which manual signals are activated which indicate to the individual persons carrying breathing devices information and/or commands like commands for withdrawal. However, the release of such commands in turn is dependent of the monitoring person who in this system, too has to supervise a plurality of data manually and has to make decisions on the basis of these data.

An essential drawback of the above-described systems resides in that the technique required for monitoring is very complicated and hence expensive, so that local institutions must make high investments in order to guarantee optimum safety of persons like firemen working in dangerous areas. In addition, there is no compatibility between such systems and the already existing equipment like

breathing devices and radio devices, so that additional investments are required.

Basing on the above-described prior art it is a p r o b l e m of the present invention to provide a method for monitoring at least two people carrying out a time-limited activity using an external respiratory air supply, which method guarantees a high working safety for people working in dangerous areas with a relatively simple and compatible technology of devices which particularly falls back upon existing devices. Furthermore, it is a p r o b l e m of the present invention to provide an apparatus for monitoring at least two people carrying out a time-limited activity using an external respiratory air supply which can be manufactured at low cost and which, in particular, is compatible with existing apparatuses.

In a method according to the present invention the s o l u t i o n of these problems provides that the time spent in the operation area is calculated according to the formula:

$$t_{work} = \frac{V_{respiratory\ air\ min} - t_{advance} - (t_{advance} \cdot \alpha)}{dQ}$$

wherein t_{work} is the time spent in the operation area, $t_{advance}$ is the time needed to reach the operation area, α is a safety factor, $V_{respiratory\ air\ min}$ is the respiratory air supply in the breathing equipment with the smallest supply, and dQ is the average respiratory air consumption per unit time, the control center transmitting a signal to the persons in the operation area when the point of time for a safe withdrawal is reached.

Accordingly, in a method according to the invention it is provided that in a group of at least two people the respective pressure in the breathing equipment is detected, which pressure is equivalent to the respiratory air supply. Here, the

lowest pressure is used as a basis for planning and performing the operation in the operation area. This pressure must not be lower than a predetermined value of 270 bar for example, in order to avoid any safety risk. In a next step, the pressure in the breathing equipment with the smallest supply of respiratory air is determined at the time of arriving in the operation area and is transmitted to the monitoring person who calculates the consumption for the time needed for reaching the operation area, multiplies it by the safety factor α and puts down this value as the time interval for the withdrawal. Normally, $\alpha = 2$ has to be chosen for the safety value. The transmission of the required data is effected through a common radio device which is available on part of the monitoring person and on part of at least the leader of the team. This transmission may take place orally or also in the form of data telegrams, which data telegrams may be used for example also for activating a signalling device, for example a visual and/or acoustical signal.

According to a further feature of the invention it is provided that the data are transmitted in dependence of and/or with the information of an identification of the individual breathing devices. Thereby it becomes possible that one monitoring person monitors several teams at a time, since the data are provided with a code, so that this code can be received and processed only by the corresponding encoded receiving units of the breathing equipment.

According to a further feature of the invention it is provided that the control center for monitoring first detects the respiratory air supply in the breathing equipment with the smallest supply at the beginning of the operation and thereafter the respiratory air supply in this breathing equipment at the time of reaching the operation area and that the difference from these values is used for calculating the time that can be spent in the operation area.

In order to further improve the safety of the method according to the invention it is provided according to a further feature of the invention that the calculation of

the individual times is effected in a computer-assisted fashion. Here it is provided that the monitoring person is equipped for example with a mobile computer (laptop) which is supplied via a receiving module with data of the breathing equipment to be monitored. Through a corresponding software program the stay time and particularly the withdrawal time are calculated from these data, while simultaneously outputting signals to the team(s) to be monitored, particularly to the leader of the team(s), in order to guarantee that the withdrawal of the team(s) will take place in due time.

Preferably, the end of the stay time in the operation area is indicated by an acoustical and/or visual signal. The transmission of the signals and/or data to be transmitted is in particular effected automatically, i.e. independently from persons, so that any wrong control is essentially excluded.

For the s o l u t i o n of the above-mentioned problems it is provided in an apparatus according to the present invention that the same includes a data collection and evaluation unit for the collection and evaluation of data which are received from the individual mobile units assigned to persons, wherein at least one mobile unit includes a means for setting and transmitting data sets representative of a respiratory air supply, which data set can be transmitted from the mobile unit to the collection unit, said mobile unit comprising an output unit for displaying the point of time of withdrawal from the operation area, which output unit can be activated through the collection unit.

According to a further feature of the invention it is provided that the mobile unit is connected to a breathing device via a transducer, so that an automatic data collection is effected. The mobile unit particularly has an operating or displaying device serving for inputting and displaying data.

For localizing persons who are likely to have had an accident it is provided that the mobile unit is connected to a localizing device, for example a GPS trans-

mitter. If the communication between the monitoring person and a group or a person is interrupted or if data – for which confirmation of receipt is provided in particular - cannot be transmitted anymore, a group or person having an accident can be quickly localized and rescued from the dangerous area.

Finally it is provided that the collection unit, the mobile units and/or the device for setting and transmitting data sets representative of a respiratory air supply have housings which are designed in an explosion-protected manner and which preferably consist of metal. Devices which are formed in this manner can be used also in surroundings with an existing danger of gas explosion. Making the housing of metal has the advantage that the device is sufficiently stable, so that damages to the device are excluded even under difficult conditions.

Further features and advantages of the invention will become apparent from the following description of the attached drawing showing a preferred embodiment of a device according to the invention for carrying out the method according to the invention. In the drawing it is shown by:

Figure 1 a device for monitoring a person carrying out a time-limited activity using an external respiratory air supply;

Figure 2 a central unit as a constituent part of the device according to figure 1; and

Figure 3 an operating device as a constituent part of the device according to figure 1.

A device for monitoring at least two people carrying out a time-limited activity using an external respiratory air supply, especially people carrying breathing equipment, for example firemen, divers or the like, is comprised of a collection unit 1 and at least two mobile units 2 which are carried along by the people to

be monitored. Each mobile unit 2 includes a central unit 3 and a device for setting and transmitting data sets representative of a respiratory air supply, which device is formed as an operating part 4 and is connected to the central unit 3 through a connection line. In addition, said central unit 3 is connected through a connection line 6 to a radiotelephone device 7 adapted for wireless communication with said collection unit 1 and including an antenna 8 for this purpose.

Furthermore, said device according to claim 1 includes a transducer 9 which for example picks up biological parameters like the pulse and/or respiratory frequency and/or oxygen saturation in the blood of the active person and transmits these parameters to the central unit 3 when a preset value indicating danger is transmitted to the central unit 3. To this end the transducer 9 is connected to the central unit 3 through a connection line 10. Via said central unit 3 the biological parameters transmitted from the transducer 9 are further transmitted to the data collection unit 1 for evaluation and logging. These parameters assist in the decision whether the activity will be stopped or continued. Finally, the device includes a GPS antenna 11 which is connected to the central unit 3, i.e. a GPS transmitter not further shown, through a data line 12.

All the above-mentioned connection lines 5, 6 and 10 as well as data line 12 serve for data exchange and in addition to that may be provided also for the voltage supply of the respective components like the radiotelephone device 7, the operating part 4 and the transducer 9. This makes a separate energy supply such as batteries or accumulators internally of said components unnecessary, which fact is advantageous with regard to the operating part 4 and the transducer 9.

In figure 2 the central unit 3 is shown in detail. Said central unit 3 consists of an explosion-protected housing 13 and an energy supply 14 which may be plug-connected to said housing 13 in the form of a battery or a rechargeable accu-

mulator. The corresponding plug connectors are provided but are not further shown in figure 2.

The housing 13 consists of metal an includes in its interior a micro processor not further shown, a modem for data exchange, a level and signal converter as well as a capacitor for buffering the supply voltage. The housing further includes a flashing alarm lamp 15 for outputting visual signals as well as a high power source of sound 16 for outputting acoustical signals.

Furthermore, the central unit 3 has on the underside thereof various reverse battery protected sockets as interfaces for the connection of the radiotelephone device 7, the transducer 9, the GPS antenna 11 as well as the operating part 4. Next to the socket indicated by reference number 17 the central unit 1 has provided on the underside thereof a switch 18.

As a radiotelephone device 7 a common radiotelephone device is connected to the central unit 3 through a cable adapter. Accordingly, this radiotelephone device 7 may be used both for data exchange and the usual verbal communication.

The GPS antenna 11 is connected to a serial port with RS 232 standard, and this serial port may be also used for programming the central unit 3 as well as for checking and revising software stored in the central unit 3. In a corresponding switching position of the switch 18 the operating condition of the central unit 3 is indicated by a light emitting diode 19 which is also provided on the underside of the central unit 3, next to the sockets 17.

The transducer 9 consists of four sensors with analogous transmission of measuring values within a voltage range of between 0 and 5 Volts, the connection of the sensors being in the form of a 2W bus system.

The central unit 3 has a clamping lock (not shown) allowing the central unit 3 to be fixed to the belt of a person carrying the central unit and to be monitored or to the carrying strap of a breathing equipment not further shown. In figure 3 the operating part connected to the central unit 3 through the connection line 5 is shown. Said operating part 4 has a housing 20 made of metal. Within said housing 20 a display 21 is arranged having two displaying fields for displaying a digit. Above and below said displaying fields 22 push-buttons 23 are provided, by means of which the digits of said displaying fields my be set, wherein the push-buttons 23 arranged above said displaying fields will increment and the push-buttons 23 arranged below said displaying fields 22 decrement the value.

In addition, the operating part 4 may include a manometer 24 for indicating the pressure within a breathing device. For data transmission of the biological parameters a data line 25 may be provided, by means of which the operating part 4 can be connected to the transducer 9.

Furthermore, the operating part 4 includes four visual displays 26, 27, 28 and 29 which signalise particular operating conditions. Said visual displays 26, 27, 28 and 29 consist of LEDs, namely aluminium-indium-gallium-phosphate LEDs which stand out due to their particularly high intensity of light. The visual display 26 is designed in a red colour and signalises the necessity of an immediate withdrawal from the operation area. The visual display 27 is designed in a yellow colour and serves for signalising an insufficient battery voltage. The visual display 28 is designed in an orange colour and signalises an incorrect operation during the programming or actuation of the operating part 4. Finally, the visual display 29 is designed in a blue colour and indicates that the pressure is being checked.

In addition to the above-described visual displays 26, 27, 28 and 29 the operating part 4 includes further push-buttons 30, 31, 32, 33, 34, 35 and 36 among which push-button 36 is an emergency push-button which is bigger in size than

the remaining push-buttons 30, 31, 32, 33, 34 and 35. The push-buttons 30, 31, 32, 33, 34, 35, 36 are illuminated, with push-button 36 for example being coloured in red in order to emphasize its importance.

Push-button 30 serves for transmitting the current pressure in the breathing device. Push-button 31 is pressed at the beginning of the activity in order to communicate a pressure value. On arriving in the operation area push-button 32 is pressed, in order to transmit a further pressure value. On terminating the work in the operation area push-button 33 is pressed as a signal for the beginning withdrawal. Furthermore, a push-button 34 is provided, which is pressed at the end of the activity, in order to transmit a further pressure. Finally, push-button 35 is formed as a connecting push-button for making a connection to the collection unit 1. The energy supply 14 shown in figure 2 is provided as a separately operable component and has a housing 37 which may be fixed to the housing 13 of the central unit 3 by means of a quick-locking device not further shown. After detaching housing 37 from housing 13 said energy supply 14 may be directly attached to a corresponding charging device. In said energy supply 14 a number of six NiMh accumulators each having a voltage of 1.2 V are provided. These accumulators may be removed after opening said housing 37 and replaced for example by batteries of the same type. Accordingly, energy supply is possible also in a case where a possibility for charging said accumulators does not exist. Due to the capacitor incorporated in the central unit 3 the energy supply 14 may be changed during operation.

As an alternative it may be provided that said accumulators or batteries are arranged to be exchangeable within the housing 13. In such a configuration the housing 13 additionally includes a further socket 17 serving for the connection of an external charging device. The charging state of said accumulators or batteries may be indicated by visual and/or acoustical signal devices. The above-described device may be used as follows:

At least two people form one operation team with one team leader and are intended for operating in a dangerous area in which danger exists to an extent that respiratory air available there is not sufficient and/or contaminated. Each team member is equipped with a mobile unit 2 and a breathing device, each breathing device having a certain air supply indicated as a pressure existing within said breathing device by means of a manometer provided on said breathing device.

Via radiotelephones 7 that are connected to the central unit 3 of the mobile units 2 the team members are in connection with collection unit 1 which is operated by a respiratory air monitoring person and which serves for collecting data that are transmitted. Data transmission is effected in a wireless fashion via said radiotelephones 7. For data evaluation said collection unit 1 is connected to a portable computer and also has a radiotelephone 7 by means of which the respiratory air monitoring person may communicate in the usual way with the operation teams. Each central unit 3 has assigned to it a particular and individual identification number which is input in the collection unit 1 prior to the beginning of the operation. This input may be made automatically, for example by reading from a data storage, particularly a transponder, or manually by inputting an identification number. To increase the safety level of the data input the first-mentioned method should be preferred because this will substantially exclude data transmission errors.

Via said identification number a radio connection is established between said collection unit 1 and said mobile units 2, the exchange of data taking place via said radiotelephones 7 of said mobile units 2 or the collection unit 1. The registration of the mobile units 2 of a team at the collection unit 1 remains active until the end of the operation, i.e. until the input of a corresponding command in the collection unit 1. Preferably, the termination of the operation and accordingly the log-out of the mobile units 2 at the collection unit 1 are possible only after the input of a special code, in order to prevent accidental deletion of data during the

operation. As an alternative it may be provided that the connection between the mobile units 2 and the collection unit 1 is changed by an additional collection unit 1 taking over the data from the first collection unit 1 and communicating with the mobile units 2 in order to establish a new data connection and to file said data both in said mobile units 2 and in the new collection unit 1.

At the beginning of the operation the leader of the operation team will set in the display 21 the lowest possible pressure of the breathing equipment of his team. Thereafter, this pressure will be communicated to the collection unit by pressing push-button 30. The transmission takes place in the form of a data telegram of which the receipt will in turn be confirmed by the collection unit 1. Confirmed data are transmitted to the mobile unit 2 and filed in a storage there, which storage may be read and particularly printed out for example in the form of a protocol after an operation. To this end, the mobile unit 2 may be connected to a computer and/or printer via its serial interface.

Simultaneously with the transmission of the lowest pressure the operation of the team will begin and the team leader transmit the beginning of the operation by actuation of push-button 31, and the beginning of the operation will in turn be confirmed by the collection unit 1, the transmission between the collection unit 1 and the mobile unit 2 taking place in real time for example.

Upon the team reaching the operation area push-button 32 will be pressed in order to fix the time interval between the beginning of the operation and the arrival at the operation area. This transmission of data to the collection unit 1 will also be confirmed on behalf of the collection unit 1, said confirmed data being in turn filed in the mobile unit 2. At the same time the collection unit 1 will compute the time interval needed for withdrawal, taking into account a safety factor α, said computation being again based on the lowest pressure in the breathing equipment of the team. This can be made on the basis of the originally trans-

mitted pressure, without the necessity for the team leader to read and transmit a new pressure when the team arrives at the operation area.

After the computation of the time interval for the withdrawal of the team the point of time of transmission of a signal to the team leader will be fixed, which signal is displayed at the central unit 3 either acoustically and/or visually, for example by activating a flashing lamp 15 and/or the source of sound 16. A corresponding displaying action may take place also in the operating part 4 region. To this end, the visual displays 26, 27, 28 and 29 are provided.

Receiving the signal for withdrawal from the operation area, the leader of the operation team will acknowledge receipt of this signal and the beginning of the withdrawal by pressing push-button 33, so that the arrival of the team may be monitored by the collection unit 1, resulting in alarm signal being output in the collection unit 1 region if the team does not arrive at the starting point within the time calculated for withdrawal and if a corresponding signal is not transmitted to the collection unit 1 after the team has safely returned. In such a case, an organized search may be initiated, for which purpose the GPS antenna 11 in connection with a GPS transmitter not further shown is provided, through which the missing team can be localized. As a supplementary measure in such a case the flashing alarm lamp 15 and the sound source 16 in the central unit 3 region may be activated via the collection unit 1, in order to more easily find a team in the darkness or in very smoke-filled rooms.

During the operation of the teams data may be sent to or received by the collection unit 1 via the operating part 4. In this way, regular checks may be made for example of the radio connection by the collection unit 1 addressing the central unit 3 of a mobile unit 2 and waiting for confirmation. If any confirmation is not received corresponding safeguarding measures may be taken. In addition, the operating part 4 includes a push-button 36 by means of which a first priority signal may be sent to the collection unit 1, in order to signalise emergency

situations and initiate corresponding rescuing measures. Through the transducers 9 additional data like the pulse and/or breathing frequency of the carrier of the breathing equipment may be detected, in order to obtain information about the physical condition of the person being in the operation area.

Accordingly, the present invention provides for a low-cost possibility of monitoring people carrying breathing equipment in dangerous areas, the data required for monitoring being regularly exchanged and electronically processed, without the necessity of carrying out manual operations.